Preliminary Design Basis Accident Analyses of the Proposed Split Core at NIST Using ANL-PARET Code

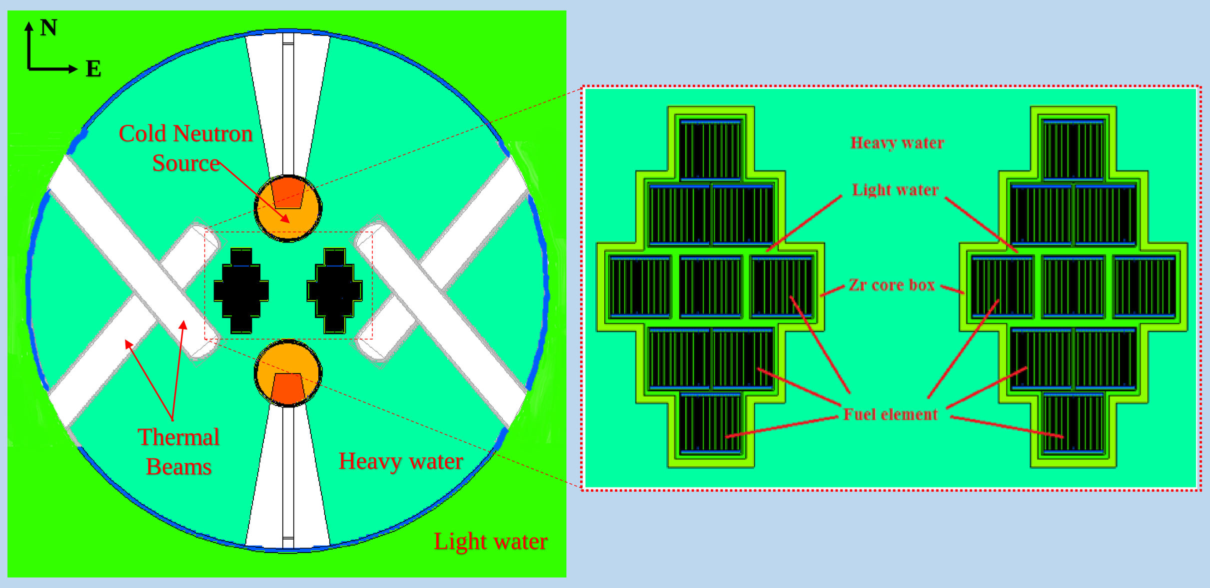
Zeyun Wu[1, 2], Robert E. Williams[1], and J. Michael Rowe[1]

[1]NIST Center for Neutron Research, 100 Bureau Drive, Mail Stop 6101, Gaithersburg, MD 20899, USA

[2]Department of Materials Science and Engineering, University of Maryland, College Park, MD 20742, USA

Overview of the Split Core Design

The proposed NIST reactor employs the standard ‘tank-in-pool’ design pattern, in which a cylindrical heavy water tank 2.5 m diameter and 2.5 m height is placed in the center of a large light water pool that functions as the thermal and biological shields. Two vertical liquid deuterium cold neutron source (CNS) are placed in the flux trap located in the north and south sides of the core. Four thermal beam tubes are placed in the east and west sides of the core at different elevations (20 cm above and below the core mid-plane) tangential to the core.



A schematic view of the reactor with horizontally split cores

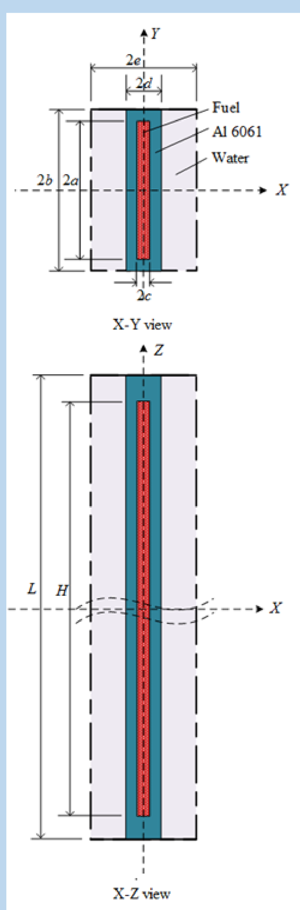
The reactor power distribution and the kinetics parameters are required for reactor safety analyses. The power density specifies the initial heat source profile for the thermal-hydraulics (T/H) model; the kinetics parameters indicate the sensitivity of the reactor power response to the reactivity change. In this study, the power density and kinetics parameters of the startup (SU) and end-of-cycle (EOC) core are determined by reactor physics calculations.

Key Parameters Required for Safety Analyses

Parameter	SU	EOC
Power peaking factor (hot channel)	3.14	2.48
Power peaking factor (avg. channel)	1.50	1.19
Prompt neutron generation time - Λ (μs)	202.61 ± 4.60	203.82 ± 4.42
Effective delayed neutron fraction (β_{eff})	0.00740 ± 0.00047	0.00717 ± 0.00041

ANL-PARET Model and Safety Analysis Criteria

The PARET code, developed by Argonne National Lab (ANL), is primarily for safety analysis of research and test reactors that use plate-type fuel elements or round fuel pins. The features of the code perfectly meet the requirements of safety analysis of the split core. For simplicity, a two-channel PARET model is developed to account for physical conditions in the hot and average channel, respectively. Each channel includes a 1-D slab geometry of fuel plate, extending from the plate centerline to the coolant centerline on both sides of the plate. Appropriate volume fractions are weighted for each channel to account for proper heat source transferred in the channel.

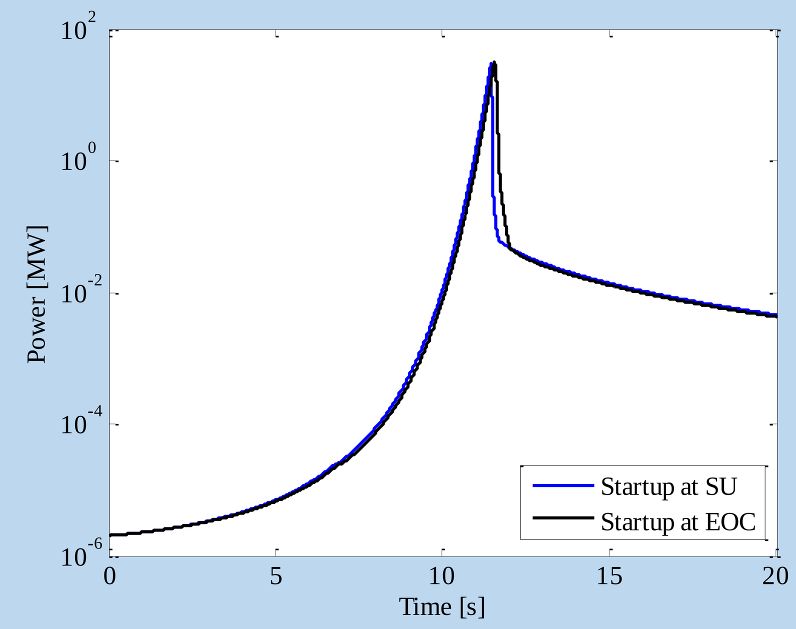


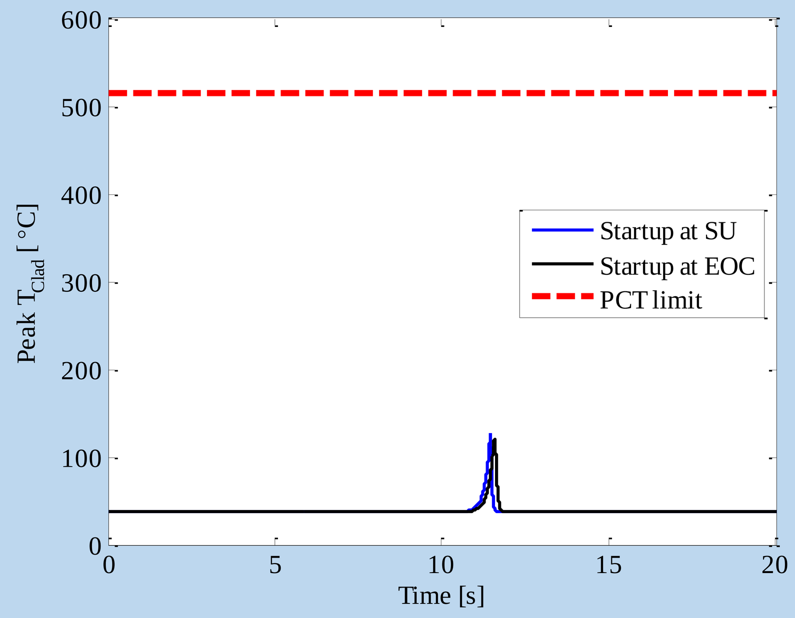
Constraints Considered in the Safety Analyses

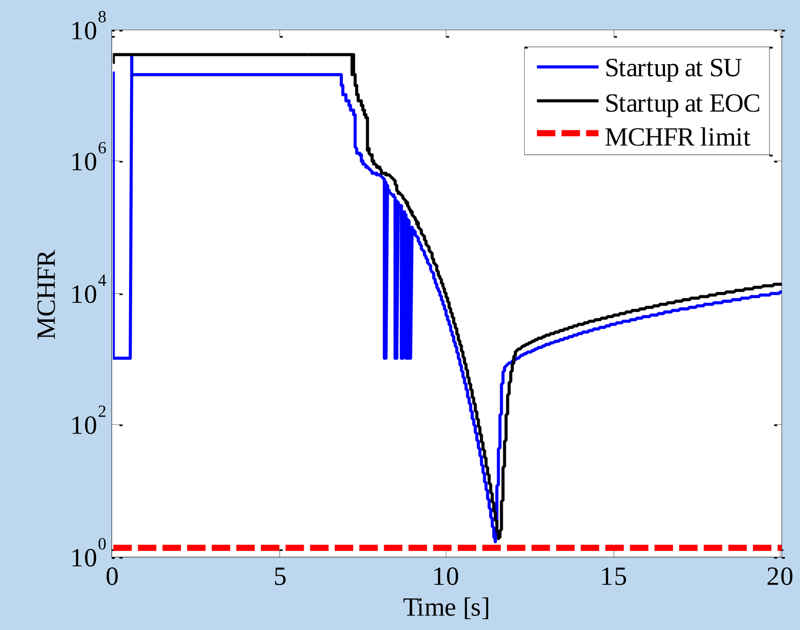
Two thermal constraints are examined during the course of the transients. The first one is **the peak clad temperature (PCT),** which is a direct indicator of the physical damage to the fuel plate. The PCT for the silicide LEU fuel must not exceed 515 °C. Another constraint is on the critical heat flux (CHF). An indicator for the CHF constraint is known as **the minimum critical heat flux ratio (MCHFR)**. The limit of MCHFR for the study is set 1.32, which is obtained from the safety report of the existing NIST reactor. To conform to current existing options in PARET, the Mirshak correlation is used to estimate the critical heat flux in the model.

Control Rod Withdrawal Start-up Accident

The control rod withdrawal start-up accident is modeled with a slow ramp reactivity insertion to a critical core from a very low power to examine the severity of the event. The reactor is initially critical and operating at a power of 2 Watts. The ramp reactivity is assumed to be inserted with a very mild rate to mimic the slow reactor start-up procedure. The reactor scram occurs with a power trip at 24 MW (120% of the full power). A time delay constant 25 ms is defined in the model to account for the finite time required for the safety rods to start the movement after scram. The control rods are assumed to move with a constant rate 1.2 m/s for scram.



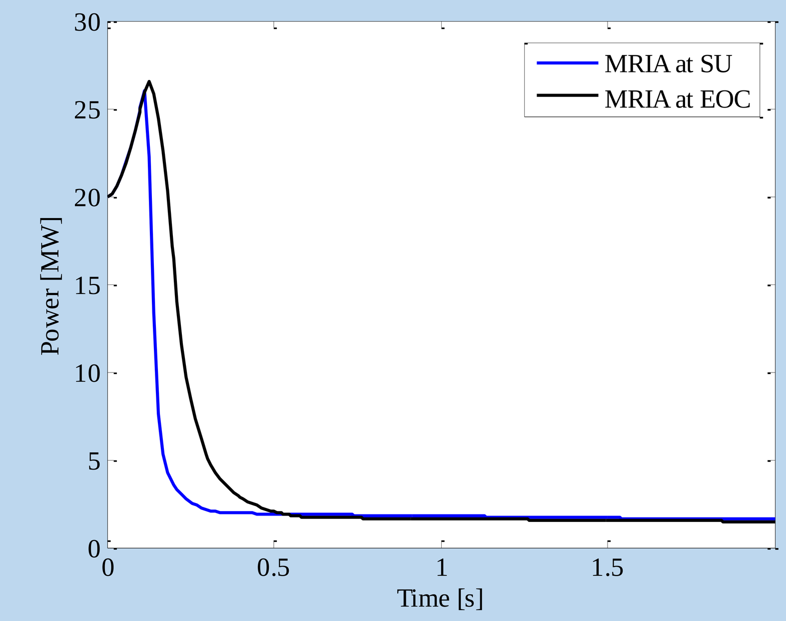


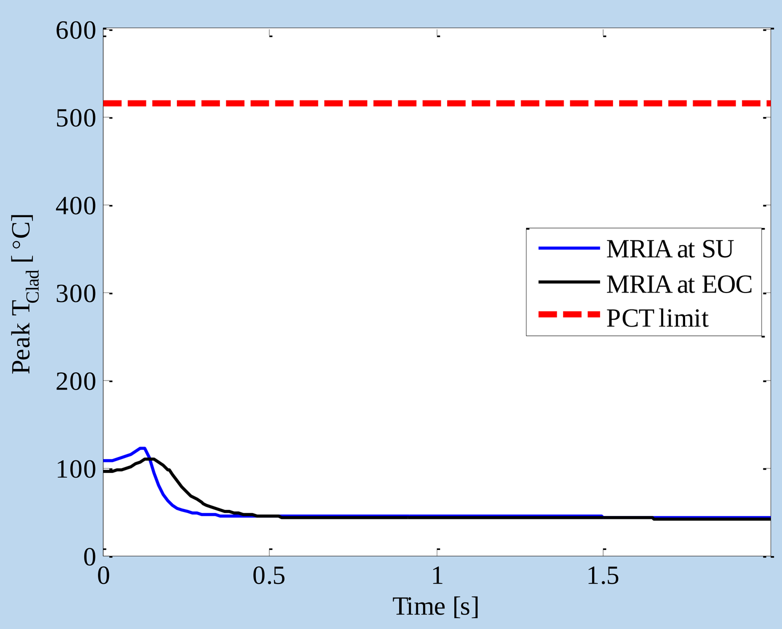


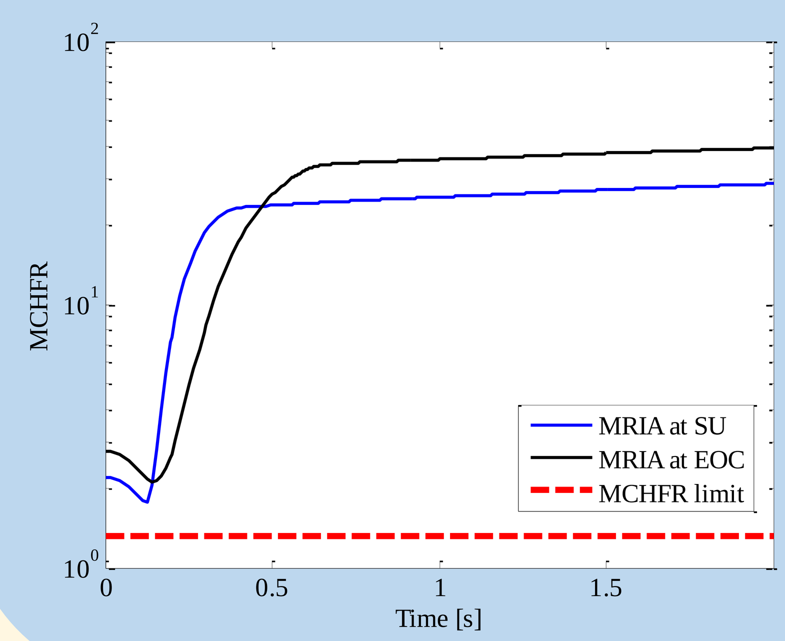
Peak values and occurring times

Core Status	SU	EOC
Peak Power [MW]	29.12	31.05
Peak power time [s]	11.45	11.56
Power trip time [s]	11.42	11.51
PCT [°C]	127.38	119.49
PCT time [s]	11.46	11.57
MCHFR	1.66	1.86
MCHFR time [s]	11.46	11.57

Maximum Reactivity Insertion Accident







The maximum reactivity insertion accident models the power excursion with a large positive reactivity inserted in the core that may be caused by experiments removed from the core. Both SU and EOC core are considered for the accident. The reactor is assumed to be initially operated at a full power of 20 MW. A large positive reactivity was inserted to the core in 0.5 seconds. The scram set point, time delay constant for the scram and the constant control rod movement speed are all assumed to be the same as the start-up accident case. For conservatism, all reactivity feedback coefficients are assumed to be zero.

Peak values and occurring times

Core Status	SU	EOC
Peak Power [MW]	26.03	26.51
Peak power time [s]	0.113	0.127
Power trip time [s]	0.098	0.098
PCT [°C]	121.99	109.99
PCT time [s]	0.127	0.141
MCHFR	1.78	2.12
MCHFR time [s]	0.127	0.141